MEMBRANE HYBRID SYSTEMS IN WASTEWATER TREATMENT

by

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CERTIFICATE OF AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative master degree and fully acknowledged within the text.

I also certify that I have written the thesis. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

The production of fresh water and the disposal of wastewater are the major challenges for the last few decades. Reverse osmosis (RO) membrane plants are extensively used for industrial water purification. The large quantities of concentrate generated by RO plant have a disposal issue especially when the plant is located inland. Due to high disposal costs, there is need to reuse. RO reject concentrate is being increasingly processed to recover additional potable water. To achieve higher recoveries alternate processes are used.

Reverse osmosis concentrate (ROC) produced from water reclamation plant can threaten the environment, if it is not appropriately treated before discharge. Membrane bioreactor (MBR) is an attractive technology. Membrane bioreactor is an efficient, cost-effective and reliable treatment system to produce high-quality water from wastewater. This study examined the use of MBR with and without activated carbon such as granular activated carbon (GAC) or powdered activated carbon (PAC) for further treating wastewater and removal of organic micro-pollutants.

Fouling is an important and inevitable phenomenon in MBR. Lower membrane fouling implies more production of water, less cleaning of the membrane, long-term operation and longer membrane life, therefore, reducing operational and capital costs. Fouling can not fully reversed in MBR by physical cleaning alone. However, the combination of physical cleaning and chemical cleaning could almost fully restore the activity of the membrane. Thus, in this study, chemical cleaning in MBR was studied and the performance was compared with that of membrane adsorption hybrid system (MAHS). Synthetic wastewater was used in this study.

The composition of this wastewater was similar to reverse osmosis concentrate (ROC) from a wastewater reclamation plant. The influence of filtration flux and chemical cleaning was studied. The cleaning chemicals such as sodium hypochlorite (NaOCl) and nitric oxide (NO) was experimentally evaluated. Low concentration nitric oxide (NO) reduced the growth of biofilms in an MBR system. NO treatment could delay the formation of new biofilm on the membrane. NO also had the superiority over

the traditionally used sodium hypochlorite (NaOCl) for backwashing as the later may have an adverse effect on the activated sludge and environment. NO treatment resulted in the reduction of the relative abundances of bacterial communities while might be encouraged in other bacterial communities.

- ***Submerged membrane adsorption hybrid system with granular activated carbon (GAC)***

In this study, the effect of GAC on fouling reduction was studied in submerged MBR. The addition of GAC into the MBR system deferred TMP development. This is because of the mechanical scouring effect by GAC as well as by the pre-adsorption of organics before reaching the membrane surface. Also, it was observed that the addition of GAC in MBR system can effective for removing DOC by 94% throughout the experiment period for 120 days. These results further showed that the addition of GAC helped to reduce organic fouling.

- ***Membrane adsorption Bioreactor hybrid system***

The operation of MBR resulted in the sudden rise of trans-membrane pressure (TMP). The sudden development of TMP was minimized by introducing activated carbon such as granular activated carbon (GAC) and powdered activated carbon (PAC) in MBR as a suspended medium. The incorporation of GAC and PAC prevented sudden TMP increase and also helped to remove an additional amount of dissolved organic matter.

- ***Submerged membrane adsorption hybrid system with powered activated carbon (PAC)***

A detailed study was made with the real reverse osmosis concentrate (ROC) from a wastewater reclamation plant. Biologically activated carbon uptakes the soluble organics, therefore MBR-PAC hybrid system showed the superior removal of organic matter in this study. After the addition of PAC into the reactor, total organic carbon (TOC) removal increased sharply and went up to 91 %. The recovery of TOC removal was due to the adsorption of organic on PAC initially and then by bioadsorption. The addition of PAC was mostly responsible for the improved filtration performance in the MBR system by modifying the sludge characteristics and the cake layer on the membrane surface. Thus, the addition of PAC in the MBR led to a superior organic removal by a combination of bio flocculation and adsorption phenomena.

- ***Biofilter***

Many wastewater treatment plants use MBR as their biological treatment step. MBR cannot remove persisting organic pollutants. Thus, in this study, the performance of granular activated carbon (GAC) biofilter and membrane adsorption hybrid system (MAHS) was evaluated for its ability to reduce effluent organic matter from MBR effluent collected from a decentralized MBR plant treating domestic wastewater. The up-flow biofilter column was packed with GAC to a height of 10 cm and 40 cm. The column was operated at a low velocity of 1.79 and 3.58 m/h and resulted in a high removal of dissolved organic carbon (DOC).

The MBR effluent consisted of eleven pharmaceuticals and personal care products (PPCPs). After a post-treatment of MF membrane-GAC adsorption hybrid system (MAHS), most of the micro pollutants were removed except for three compounds with very low concentrations. However, bisphenol A was found at the concentration of 316 ng/L at the end of the experiment.